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# The Impact of Internet Virtual Physics Laboratory Instruction on the Achievement in Physics, Science Process Skills and Computer Attitudes of 10th-Grade Students

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**Abstract** The purpose of this study was to investigate and compare the impact of Internet Virtual Physics Laboratory (IVPL) instruction with traditional laboratory instruction in physics academic achievement, performance of science process skills, and computer attitudes of tenth grade students. One-hundred and fifty students from four classes at one private senior high school in Taoyuan Country, Taiwan, R.O.C. were sampled. All four classes contained 75 students who were equally divided into an experimental group and a control group. The pre-test results indicated that the students' entry-level physics academic achievement, science process skills, and computer attitudes were equal for both groups. On the post-test, the experimental group achieved significantly higher mean scores in physics academic achievement and science process skills. There was no significant difference in computer attitudes between the groups. We concluded that the IVPL had potential to help tenth graders improve their physics academic achievement and science process skills.

**Keywords** Cooperative/collaborative learning · Interactive learning environment · Multimedia/hypermedia systems · Secondary education · Virtual reality

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## Introduction

One focus of current science teaching is to promote student understanding and application of scientific knowledge and inquiry processes with an outcome that students become good problem solvers (American Association for the Advancement of Science [AAAS] 1989; National Research Council [NRC] 1996; Yager 2000). To achieve this goal, science educators attempt to find a well-developed computer-assisted learning environment that integrates the rationales of pedagogy and cognitive-approach psychology with computers to improve science learning (Chiou 1995; Hannafin and Land 1997). In the past, however, limitations such as the shortage of equipment, limited class time for experiments, and concerns about the safety and expense of experiment decreased the effect of practical experiments. Fortunately, the advancement of information technology has made computers become powerful cognitive tools that extend the students' inquiry abilities and support science learning (AAAS 1993; Lajoie and Derry 1993; Lazarowitz and Huppert 1993; Baker 2003). The functions of providing learning materials, sharing ideas, and online simulations enable the Internet to be an effective way to support science experiments in the laboratory. Therefore, students in an Internet virtual science laboratory go through online collaborative group learning processes that can benefit every participant for cognitive and affective achievements (Barton 1998; Dede et al. 1996; Hiltz 1994; Wardle 1998; Yang et al. 2000).

CAI plays an important role in the support of classroom and laboratory science instruction. Many individual studies and meta-analysis report that students who have studied in science classrooms with CAI have better or even remarkable performance in science achievement (Wise and Okey 1983; Cavin and Lagowski 1987; Roblyer et al. 1988;

Rayner-Canham and Rayner-Canham 1990; Geban et al. 1992; Lazarowitz and Huppert 1993; Berger et al. 1994; Chang 2000, 2002), science process skills (Adams and Shrum 1990; Lazarowitz and Huppert 1993; Burchfield and Gifford 1995), and computer attitudes (Berger et al. 1994; Yin 1995) than those who received traditional instruction. However, some research findings show no significant difference between the comparative efficacy of CAI versus traditional instruction on students' science achievement (Ybarrondo 1984; Wainwright 1989; Olugbemiro 1991; Morrell 1992) or science process skills (Beichner 1990). After probing the probable causes behind these confounding research results, we found that CAI designed for students to do experiments or designed for problem-solving activities in a simulated-type science laboratory could produce a substantial effect on science achievement (Willett et al. 1983; Roblyer et al. 1988; Berger et al. 1994) and process skills (Lazarowitz and Huppert 1993). This means the type of CAI is a determinant to whether students can benefit from use. Only with those science experiments that cover hands-on and minds-on activities and permit students to be involved actively in the learning process can enhance the effects of CAI (Geban et al. 1992; Lazarowitz and Huppert 1993; Berger et al. 1994; Chang and Barufaldi 1999). Virtual reality technology integrates computer hardware and software to create a networked, real-time, and multimedia environment that can engage students in doing science activities actively and cooperatively. It is more powerful to support science learning by virtual reality technology than other traditional simulation forms (Chiou 1995; Dede et al. 1996).

Viewing from the activities involved in the process of science theory development, doing experiments and problem solving were different approaches to the same purpose (Stewart and Hafner 1991). Learning by doing science experiments has been suggested as one of the effective ways to promote the learning of science concepts, science process skills, and problem solving ability in middle schools (Funk et al. 1995; Baggott 1998; Wellington 1998). Among many problem-solving models, the model provided by an Assessment of Performance Unit [APU] (1986) reflects the practice of science experiments and problem solving simultaneously as a suitable referent for designing constructivist online science problem solving activities. The experiment problem solving model is composed of seven stages: identifying problems, transforming problems, planning, doing experiments, recording data, explaining results, and evaluating results (APU 1986). Except for science knowledge (Smith 1991), students also need to use basic science process skills (observing, inferring, measuring, communicating, classifying, and predicting) and integrated science process skills (identifying variables, constructing graphs, describing relationships among variables, acquiring and processing data, designing investigations, analyzing investigations, and experimenting) to carry out every stage of problem solving (Ostlund 1992; Funk et al. 1995). Once an ideal online virtual science laboratory is established, the students' science academic achievement and the performance of process skills will be raised. Another function of CAI in this technological period is to cultivate students' positive computer attitudes and, in turn confidence in using computers. Integrating computer technology into science teaching is valued by science educators; however, little research has been done concerning whether this will promote secondary students' computer attitudes.

Another rationale for the design of the IVPL is the spirit of social constructivism. The application of constructivist learning principles on science instruction and CAI were extensive (Driver et al. 1994). After reviewing the related literature (Driver et al. 1994; Gredler 1997; Morrison and Collins 1995; Yang and Heh 2001), four learning principles of constructivism were synthesized:

1. Learning is an active process including both personal and social construction. Learners, based on their own prior knowledge or/and experience, extend the system of knowledge through personal work or interaction with other sources in the learning environment. Learners are given more responsibility and ownership for learning to structure knowledge and solve problems actively according to their own interests, needs, and learning purposes.
2. Set learners in a collaborative learning community for developing, testing, and modifying their ideas and sharing the intelligence of others by means of dialogue, debate, discussion, and negotiation.
3. To gain practical knowledge and skills for other situations, learners have to be furnished with tools and resources to solve authentic problems.
4. It is essential to provide learners with learning scaffolds to excite the zone of proximal development.

More and more researchers of CAI view computers as useful tools to develop the domain knowledge or the cognitive skills of students (Hannafin 1992; Lajoie and Derry 1993; Morrison and Collins 1995; Wilson 1995). Many designers of educational technology believe that it was a trend to build computer learning environments based on a constructivist approach (Rieber 1993; Wilson 1995). For this reason, an ideal computer learning environment should contain many online software tools (e-mail, BBS, search engine, gopher), online resources, and additional assistant tools (online dictionary, navigator, editing software, discussion tools, online notebooks) to empower learners with active learning opportunities and increase communication with others. Moreover, the power of data processing and

the storage capacity of computers made it possible to record the online behaviors of learners that would prove to be helpful to cultivate reflection and the metacognition abilities of the students. Teachers or other domain experts could give online guidance and assistance as scaffolds to excite the students' zone of proximal development. The facts mentioned above show that current computer technology has paved a way for building computer virtual learning environments which are conformed to constructivists learning principles (Lajoie and Derry 1993; Wilson 1995; Boyle 1997; Baggott 1998; Wardle 1998).

In view of the research background mentioned above, the purposes of this study were to investigate the impact of the Internet virtual physics experiments on the physics academic achievement, science process skills, and computer attitudes of tenth grade Taiwanese students. The specific research questions this study addressed are as follows:

1. What is the impact of IVPL instruction on students' physics academic achievement compared to a traditional one?
2. What is the impact of IVPL instruction on students' science process skills compared to a traditional one?
3. What is the impact of IVPL instruction on students' computer attitudes compared to a traditional one?

According to these three research questions, three research hypotheses are listed below:

1. Those students who experienced IVPL instruction will have significantly better physics academic achievement than that of those who received traditional instruction.
2. Those students who experienced IVPL instruction will have significantly better science process skills than that of those who received traditional instruction.
3. Those students who experienced IVPL instruction will have significantly better computer attitudes than that of those who received traditional instruction.

The findings of this study will contribute to our understanding of the learning outcomes of Internet virtual science instruction and provide empirical evidence of the merit of CAI to policy makers.

## Methodology

A two-group pre-test–post-test design was used in this study. The willingness of teachers and students, the number and quality of school computer systems, and the permission of school administrators are all prerequisites required to execute this study. One-hundred and fifty (85 boys and 65 girls) tenth graders were randomly sampled from four classes at one private senior high school who conformed with the above conditions in Taoyuan Country, Taiwan, R.O.C. Graduated from junior high schools, they possessed a basic knowledge of physics, experience with physics experiments, and the ability to operate computers. Because the class organization could not be reorganized, a quasi-experimental research method was used in this study. The classes were divided into an experimental group and a control group with 75 students randomly assigned to each group. The experimental group received the Internet virtual laboratory instruction in the original classroom and in a computer classroom. The control group was instructed in a traditional laboratory setting.

No matter whether in an experimental or control group, the student groups were sub-divided into smaller units composed of five students and assigned by a S-type grouping method. Each member of every group possessed a different level of academic achievement. One student functioned as the group leader, one as a recorder, and three as coworkers. Before the beginning of this study, all the students attended a computer awareness course (six-class sessions) to learn the features of computers and the use of some software programs to decrease a Hawthorne effect in the experimental group. The experimental and the control group were taught by a computer teacher who had a Master degree in electric engineering and five years teaching experience. This teacher was the original physics teacher of these four classes and a member of the distance learning center at the sample school. The study lasted six weeks, during which time the students attended classes three 50-min periods per week.

### Software

The Internet Virtual Physics Laboratory (IVPL) was a virtual experiment providing a visualized social learning environment creating simulated experiment situations on the Internet (Kuo et al. 2000; Yang and Heh 2001). The rationale for designing the IVPL was derived from the findings of research concerning physics alternative conceptions in mechanics, electricity, and optics (Wandersee et al. 1994), cognitive and social constructivist learning theories (Perkins 1991; Driver et al. 1994), the example of computer-assisted learning physics (Lajoie and Derry 1993; Dede et al. 1996), and suggestions of senior high school physics teachers and researchers. We expected the IVPL would support the secondary students' understanding abstractive physics concepts, cooperative problem solving processes when doing physics experiments, and supplementing the insufficiency of equipment in the school.

The IVPL consisted of four experiments: (1) "Freely Falling Objects," (2) "Energy Conservation," (3) "Image of Lens," and (4) "Wheatstone Bridge." The prototype and contents of the IVPL were evaluated by two educational

technology experts and two senior high school physics teachers. Twelve tenth graders were selected randomly from a high school different from the sample school who attempted all four experiments in the IVPL (every three students as a group to conduct an experiment). Suggestions received from them were revised or modified, and a formal version of the IVPL was finished. There was some change in the content, but the number of experiments remained the same.

### Classroom and IVPL Learning Activities

Student groups studied the definitions of essential physics concepts and laws of mechanics, optics, and electricity involved in every experiment in their classroom before they entered the IVPL. Once they logged in the IVPL and undertook their learning in the computer classroom, the IVPL software allowed students to perform every experiment using different virtual tools provided by the IVPL to observe the physics phenomenon, measure the amount of variables, record and analyze data by way of plotting and tabulation, and reflect the results of the experiments.

The IVPL activities were integrated into a sequence of the problem solving learning activities. To allow student groups to work at their own pace, each group had access to two microcomputers in the IVPL learning procedure described in the following section.

### IVPL Learning Procedure

The problem solving stages and corresponding activities performed by the students are described as follows. To demonstrate the design of the IVPL, we used experiment one ("Freely Falling Objects") as an example for illustration.

#### *Identifying Problems*

The first screen provided for students was a multimedia animation to show an everyday physics phenomenon. Students had to describe the animated phenomena, write down the physics concepts behind it, and describe the reasons why they judge the animation content belonged to one kind of problem of four possible candidate responses. They also were required to give an everyday experience involving the same physics concept as the animated phenomenon. Every student group entered these descriptions into their virtual experiment handbook (Fig. 1).

#### *Transforming Problems*

In this stage, students read the experiment purposes, tried the virtual experiment tools the IVPL provided, and watched a video presenting the problem situation (Fig. 2). After this, the student groups tried to find all of the variables that were involved in the experiments.

#### *Planning*

According to the experiment proposes, accessible virtual tools, and the problem situation, students designed a plan for doing the experiments in a group discussion.

#### *Doing Experiments*

Following the procedures that were planned in the last stage, students used the virtual tools to do experiments. In experiment one, as an example, every group had to operate virtual tools (vertical ruler, horizontal ruler, protractor, a ruler for conversion proportion scale) to measure the distance of a ball from an elevated location to the ground. A timekeeper and calculator provided by the IVPL helped students to calculate the mathematical relations of time, distance, speed, and acceleration more accurately and quickly (Fig. 3).

#### *Recording Data*

Students recorded the date in tables and plotted the data collected from the experiments (Fig. 4).

#### *Explaining Results*

Based on the data analyzed by plots and tabulations, students gained results. They interpreted the meanings of the plot, the relation of the variables, and drew conclusions.

#### *Evaluating Results*

By discussing the if-type and why-type questions addressed by the computers (which were provided by the physics teachers) and answering an online two-item quiz, students could test the extent of their understanding. The process also encouraged reflection. If they could not give correct answers and reasons for these items, they reviewed the results and redid the experiments.

### Control Group

Students in the control group studied the same learning materials as those in the experimental group, except they did not use the IVPL learning activities. Their learning activities included classroom lectures and laboratory work only, and the classroom-laboratory work was characterized by a cookbook-form instructional mode.

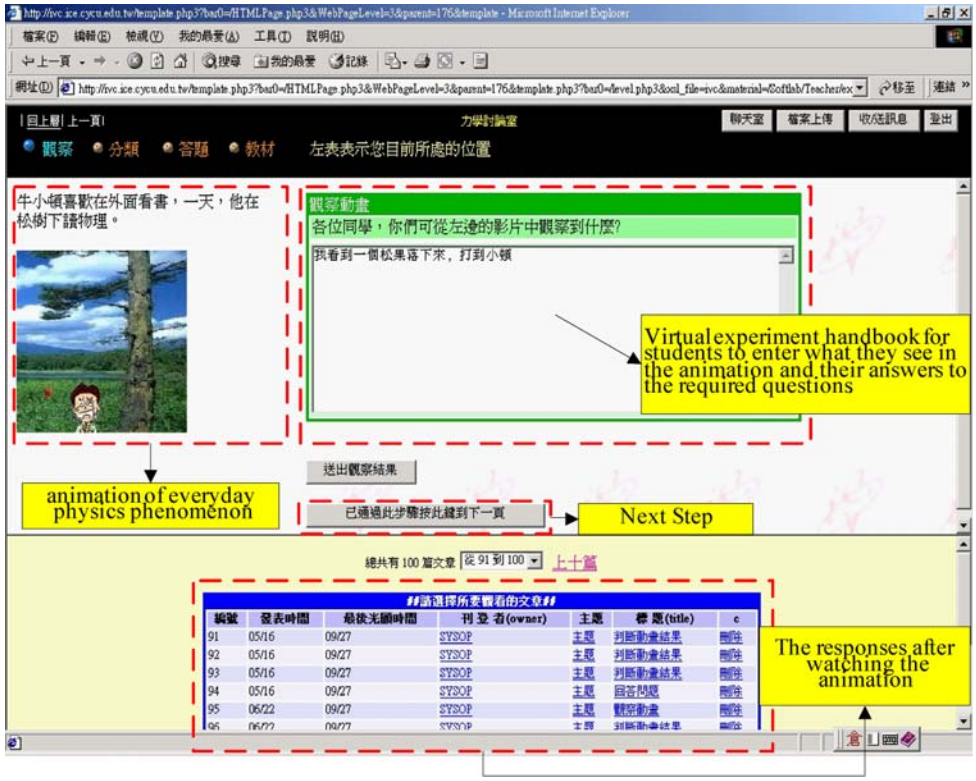


**Fig. 1** Students entered descriptions into the virtual experiment handbook

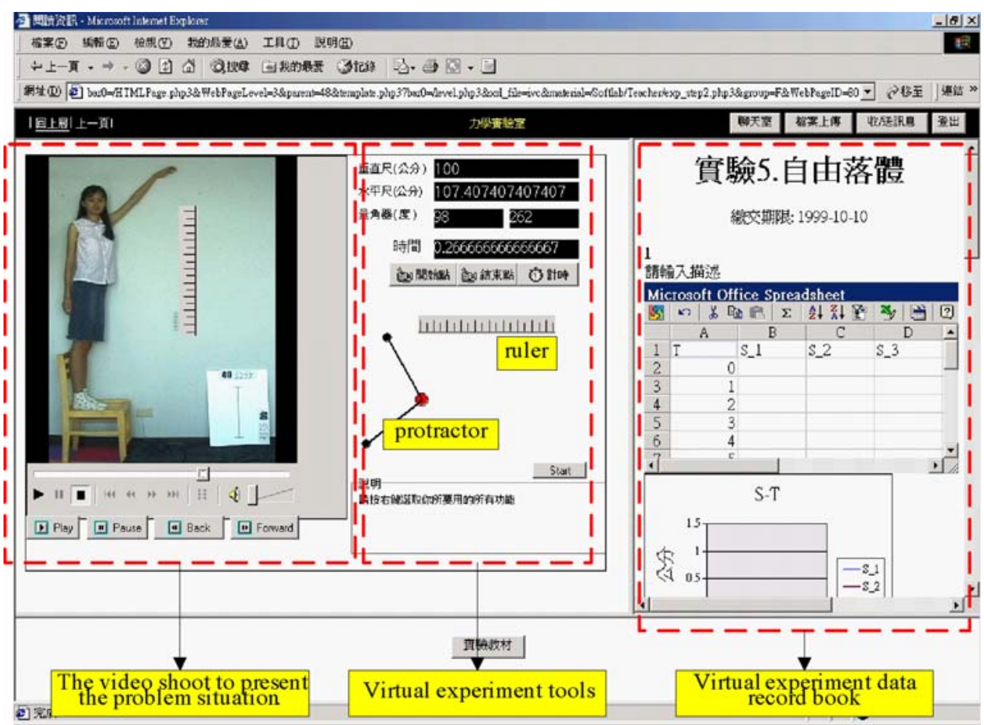


**Fig. 2** A video shoot to present the problem situation

## Instruments

### *Physics Achievement Test (PAT)*

In order to assess the teaching effects of the PIVL, the PAT was developed. Concept analyzing the senior high school physics textbooks and making of a two-way specification table as a blueprint, we edited the items for the test in mechanics, optics, and electricity. There were 45 items for test rehearsal given to 180 tenth graders from five classes of a senior high school (not the same as sample school) in Taoyuan Country. The test rehearsal lasted 50 min. Forty

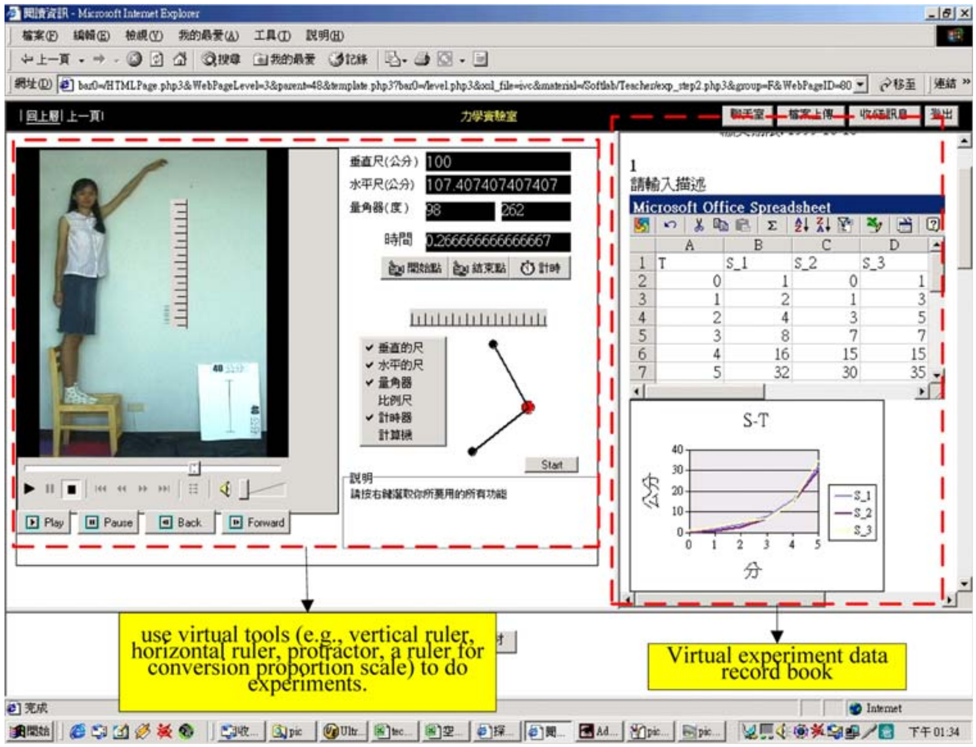


**Fig. 3** Virtual tools for student groups to ding experiments

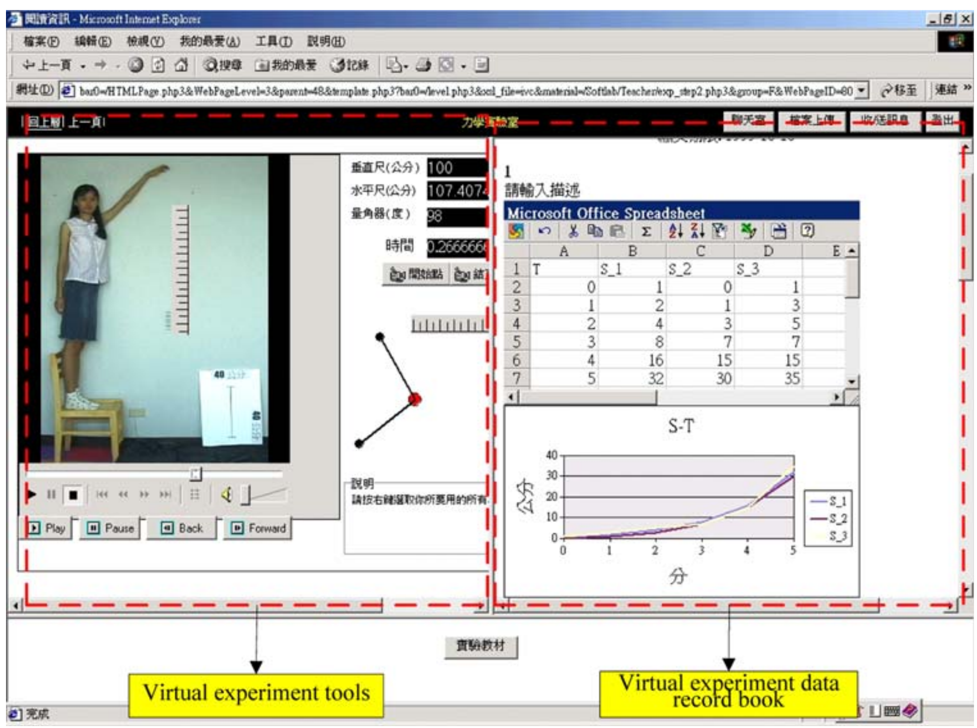


**Fig. 4** Students filled data into the table and plotting provided by IVPL

items, whose difficult indexes were between 0.35 and 0.62, were chosen according to the item analysis results of the rehearsal items. After the formal test was completed, two senior high school physics teachers and one physics professor were invited to examine the items of the test for content validity. The internal consistency coefficient (Cronbach $\alpha$) was 0.73.

*Science Process Skills Tests (SPST)*

Revised by Cheng et al. (1990), the Science Process Skills Test was adopted in this study to assess the performance of the basic and integrated science process skills of the students. The SPST was a test for seventh to twelfth graders to assess their performance of science process skills. One

point was given if one item was correct and the highest score was 36 points. Those who gained higher scores had better performance of science process skills.

The expert validity of the SPST was established and the internal consistency of Cronbach's coefficient was 0.86 (Cheng et al. 1990). The four reasons for using SPST were: (1) the consistency of the content of science process skills between SPST and this study, (2) independent of specific subject matter, (3) high reliability and validity, and (4) the suitability for tenth graders.

### *Computer Attitudes Scale—Senior High School Version (CAS)*

The Computer Attitudes Scale—Senior High School Version (CAS) developed by K.Y. Yang and M.W. Chen (unpublished) was used as an instrument to access the computer attitudes of the two groups of students before and after the PIVL application. It employed a 5-point Likert scale in which the students put a check on the elective item. In accordance with students' comments "Strongly Agree," "Agree," "No Comment," "Disagree," and "Strongly Disagree," 5, 4, 3, 2, or 1 point would be given in the order of "Strongly Agree" to "Strongly Disagree" for the obverse-direction items (13 items). One to five points would be given in the above order for reverse-direction items (15 items). Since the CAS consisted of 28 items, the highest and lowest points were 140 and 28. The higher the score, the better and more positive the computer attitudes were. Ten minutes were allotted for students to answer all items.

Selected from several computer attitudes scales, CAS was developed on the basis of the framework provided by Loyd and Gressard (1984). One-hundred and fifty tenth graders were randomly sampled from Taoyuan Country to take part in a preliminary test. Twelve items that had a low corrected item-total correlation (<0.3) in the rehearsal version were deleted and 28 items remained as the formal version of the CAS. "Computer anxiety" (eight items), "Computer confidence" (10 items), and "Computer liking" (10 items) were three subscales of the whole scale. Besides content validity, the internal consistency of Cronbach's coefficient of the whole scale and three subscales was 0.93, 0.77, 0.85, and 0.88, respectively. It was perceived that the CAS was a reliable and valid instrument for the assessment of computer attitudes.

## Results and Discussion

The results on the tests of the students' entry-level physics academic achievement (we used means of mid-term examination grades as entry-level physics academic achievement of both groups), science process skills, and computer attitudes indicated no significant difference in the mean scores between the experimental group and the control group on the pre-test (Table 1). Therefore, both groups were equal in their prior physics knowledge, science process skills, and computer attitudes.

The mean post-test scores measuring the students' physics academic achievement, science process skills, and computer attitudes were treated by use of a *t*-test. Mean scores, standard deviations, and *t*-values are presented in Table 2. These results indicated that the post-test mean scores of the PAT, SPST, and CAS of the students in the experimental group were significantly higher than those of the control group.

The students' pre- and post-test mean scores on physics academic achievement, science process skills, and computer attitudes were treated by analysis of covariance ANCOVA (pre-test mean scores served as a covariate). In order not to violate the assumption of homogeneity, we calculated three *F*-values of the interactions between independent variables and covariates (pre-test grades of PAT, SPST, and CAS), respectively, and the values were 0.36 ($p > 0.05$), 3.67 ($p > 0.05$), and 15.73 ($p < 0.01$). These three values meant that the assumption of homogeneity of the within group regression coefficient were not rejected in the first two relations and was rejected in the third (Stevens 2002). Thus, we examined the experimental treatment on the students' physics academic achievement and the science process skills after eliminating the covariate by ANCOVA and using a Johnson-Neyman method to test the effects of the experimental treatments on the students' computer attitudes (Stevens 2002).

As Table 3 shows, when the effect of the covariant (entry-level physics academic achievement) on the dependent variable (post-test of PAT) was deleted, the variance resulting from the independent variable (IVPL) was significant statistically ($F = 13.87$, $p < 0.01$). This meant that the physics academic achievement had significant differences between the experimental and the control groups owing to the treatment of the independent variable (IVPL). In order to do a post-hoc comparison, we calculated the adjusted means of the experimental group ($M = 60.94$, SD = 1.32) and the control group ($M = 53.97$, SD = 1.32) and used the Scheffé method (Table 4). The mean difference value (6.89) between the experimental group and the control group was significant ($p < 0.01$). Therefore, we could say that learning through the IVPL had a positive and significant effect on the students' physics academic achievement. This result was the same as many findings (Burns and Bozeman 1980; Hallworth and Brehner 1980; Cavin and Lagowski 1987; Roblyer et al. 1988). Moreover, these research studies used a computer-based problem solving approach in the learning environments similar to the IVPL. The results of

**Table 1** Pre-test mean scores, standard deviation (SD), and *t*-test of physics academic achievement, science process skills, and computer attitudes of experimental group ($N = 75$) and control group ($N = 75$)

| Variables | Experimental group mean (SD) | Control group mean (SD) | *t*-Test |
|---|---|---|---|
| Physics academic achievement | 85.41 (5.76) | 85.09 (6.06) | 0.33 |
| Science process skills | 23.48 (5.15) | 23.61 (5.09) | 0.16 |
| Computer attitudes | 104.52 (13.07) | 104.64 (13.65) | 0.06 |

**Table 2** Post-test mean scores, standard deviation (SD), and *t*-test of physics academic achievement, science process skills, and computer attitudes of experimental group ($N = 75$) and control group ($N = 75$)

| Variables | Experimental group mean (SD) | Control group mean (SD) | *t*-Test |
|---|---|---|---|
| Physics academic achievement | 61.01 (11.31) | 53.89 (12.15) | 3.72** |
| Science process skills | 26.43 (5.15) | 23.69 (5.09) | 4.03** |
| Computer attitudes | 108.13 (14.05) | 103.01 (16.07) | 2.10* |

*$p < 0.05$, **$p < 0.01$

**Table 3** ANCOVA summary of experimental treatment on PAT grades

| Source | SS | DF | MS | *F* |
|---|---|---|---|---|
| Covariance | 1058.98 | 1 | 1058.98 | 8.05** |
| Between groups | 1823.19 | 1 | 1823.19 | 13.87** |
| Total | 19327.15 | 147 | 131.48 | |

**$p < 0.01$

**Table 4** Summary of post-hoc comparison (Scheffé method) on PAT grades

| Groups | Mean difference (E – C) | SE |
|---|---|---|
| Experimental group (E)—Control group (C) | 6.98* | 1.87 |

*$p < 0.01$

this study agreed with them (Rayner-Canham and Rayner-Canham 1990; Geban et al. 1992; Lazarowitz and Huppert 1993; Chung and Tung 2000). Even though the content was different, the effects of the virtual experiments in the IVPL on the students' learning achievement were identical to some research that showed computer-simulated experiments could significantly promote learning achievement (Rivers and Vockell 1987; Soon Choi and Gennaro 1987). In view of the above, it could be said that the PIVL had a significant promotional function for tenth graders' physics learning.

Some researchers found that computer-simulated experiments could enhance more active involvement in the learning process and more understanding of science concepts (Rivers and Vockell 1987; Soon Choi and Gennaro 1987; Nakhleh and Krajcik 1992). The learning principles of constructivism and cognitive psychology claimed that the more opportunity for active learning for the students the more fruit of the efforts they gained (Driver et al. 1994; Yager 1995). It was evident from the field observations that the students liked to use the simulated experimental tools provided by the IVPL to do experiments. This is a partial cause as to why students' learning achievement was promoted by learning within the IVPL.

As seen in Table 5, ANCOVA procedures indicated that when the effect of the covariant (pre-test of SPST) on the dependent variable (post-test of SPST) was deleted, there was significant main effects ($F = 17.29$, $p < 0.01$) on science process skills between the two groups. After calculating the adjusted means of the experimental group ($M = 26.43$, $SD = 0.47$) and the control group ($M = 23.68$, $SD = 0.47$) and using the Scheffé method to compare the mean differences between these two groups (Table 6), we found that the science process skills of the experimental group were significantly better than the control group (the mean difference value was 2.76, $p < 0.01$) because of the experimental treatment (IVPL). Since doing science experiments was admitted as the main way to master science process skills (Hofstein and Lunetta 1982; Funk et al. 1995; Barton 1998) and students in constructivist classrooms could use the basic process of science better (Yager 1995), the results of this study corresponded to the findings and conclusions of Lazarowitz and Huppert's (1993) study. The results of this study not only illustrate the interrelation among science process skills, doing experiments and problem solving, but they also indicate the potential of the content and virtual tools of the IVPL to improve science process skills.

Because there was significant interaction between the independent variable and the covariate (pre-test of CAS)

**Table 5** ANCOVA summary of experimental treatment on SPST grades

| Source | SS | DF | MS | *F* |
|---|---|---|---|---|
| Covariance | 131.05 | 1 | 131.05 | 7.49** |
| Between groups | 285.17 | 1 | 285.17 | 17.29** |
| Total | 2425.25 | 147 | 16.50 | |

**$p < 0.01$

**Table 6** Summary of post-hoc comparison (Scheffé method) on SPST grades

| Groups | Mean difference (E – C) | SE |
|---|---|---|
| Experimental group (E)—Control group (C) | 2.76* | 0.67 |

*$p < 0.01$

($F = 15.73$, $p < 0.01$), the within group regression coefficient was not homogeneous and the ANCOVA was replaced by the Johnson-Neyman method to find the cross point of the two regression lines and the locations of the significant difference. The results indicated the grades corresponded to the cross point was 114.2 (point A in Fig. 5) and that of the two points of significant difference were 105.6 or 123.6 (points B and C in Fig. 5). This meant that for the students whose pre-test grades on the CAS were below 105.6, the traditional laboratory instruction was more help to their computer attitudes. For the students whose pre-test grades on the CAS were above 123.6, learning through the IVPL would contribute more to their computer attitudes. As regards the students whose pre-test grades on the CAS were between 105.6 and 123.6, no significant difference was observed of computer attitudes between the experimental group and the control group, namely, we could not determine whether tradition laboratory instruction or learning by virtual experiments in the IVPL had more effects on the students' computer attitudes. Some researches found that CAI could raise the students' computer attitudes (Kulik et al. 1985; Berger et al. 1994; Yin 1995; Roblyer et al. 1988), and we found a similar result in this study.

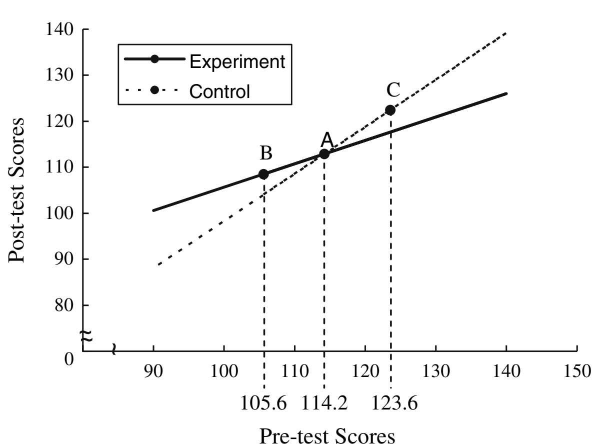


**Fig. 5** Crossing point (**A**) and significant difference points (**B** and **C**) of the regression lines for experiment group and control group

Generally, the students' computer experience was derived from the availability of home and school computers and the number of g computer classes taken in school (Shashaani 1997). Based on the result of this study, we found that both teaching method and students' prior computer attitudes were two factors that improved the students' computer attitudes. Even though there was some research that indicated a positive relationship between computer experience and computer attitudes (Levin and Donitsa-Schmidt 1997; Yaghi 1997).

## Conclusions and Suggestions

To promote science learning achievement through CAI has been the focus of educational technology. A good computer virtual learning environment is an interdisciplinary product that merged the rational of science learning and educational technology. Active and meaningful learning conditions will be accomplished through CAI environments due to the development of computer tools. The results of this study show that there were significant differences of science process skills, physics academic achievement, and computer attitudes (for those whose pre-test score of CAS was above123.6) between the experimental group and the control group. Because the IVPL can promote students' science knowledge and science process skills, it is an effective way to use the IVPL as a computer assisted learning environment for tenth graders to cultivate their scientific literacy. Because prior computer attitudes and computer experience of students would affect the effects of CAI, it was necessary for teachers to pay attention to this individual difference and give more encouragement to those who have less computer experience.

The pedagogical advantages of combining virtual reality technology with science problem-solving activity to set a constructivist learning environment also could be found from the IVPL. Finding of this study imply once again that problem-solving is really beneficial for secondary school students to learn sciences. The use of the IVPL to meet the goals of innovating science curriculums for secondary schools in Taiwan is needed to develop the basic competence of the students.

The research and developments of CAI was a continuous and innovative process with the advancement in computer technology and the learning rationale. If we want

to cultivate intelligent students and display the specific function of technology completely, the computer learning environment must provide every tool possible that could be used by students to collect intelligence distributed throughout their surroundings. Creators of CAI from related domains should work with collective wisdom and concerted efforts in the processes of analyzing, designing, developing, and evaluating a practicable and beneficial learning environment. It is better to exploit essential software tools according to the needs of the learning activities to reach the supportive and facilitative functions of CAI.

More research is expected to pierce the online learning process and the under-lying meaning of every online interactive learning behavior in order to enhance human learning as soon as possible.

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